

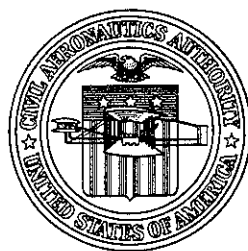
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M A N U A L

14 AIRCRAFT PROPELLER AIRWORTHINESS

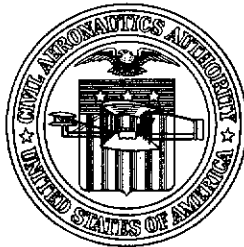


December 1, 1938

U. S. CIVIL AERONAUTICS AUTHORITY

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14 AIRCRAFT PROPELLER AIRWORTHINESS



December 1, 1938

United States
Government Printing Office
Washington : 1938

CIVIL AERONAUTICS AUTHORITY MANUAL

INTRODUCTORY NOTE

This manual is supplementary to the Civil Air Regulations, Part 14, referred to herein by the Code of Federal Regulations designation 6 CFR 14. The material contained herein is intended to explain and interpret the various requirements of 6 CFR 14, to expedite the presentation of the desired technical data, and to outline what is considered acceptable practice in certain instances.

It should be understood that any method which can be shown to be the equivalent of one set forth in this manual will be equally acceptable to the Authority. Likewise, any interpretation herein shown to be inapplicable to a particular case will be suitably modified for such case on request. In either event such acceptance or modified interpretation will be effective as and when issued prior to subsequent incorporation herein. This manual will be revised from time to time as equally acceptable methods, new interpretations, or the need for additional explanation are brought to the attention of the Authority.

The material in this manual is arranged for direct correspondence with the requirements. For example, CAAM 14.1-A3 refers to a specific breakdown of 6 CFR 14.1. On the reverse side of this page will be found a form for convenience in maintaining a record of subsequent revisions.

REVISION No.

DATE

PAGES

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CIVIL AERONAUTICS AUTHORITY MANUAL

14 AIRCRAFT PROPELLER AIRWORTHINESS

.0 GENERAL

.00 PROVISION FOR RATING

1. It should be noted that 6 CFR 14 concerns the rating of propellers for use on engines specifically, and on aircraft only insofar as the complete powerplant unit is eventually installed and operated on an airplane. An operation limit specified in accordance with this chapter approves the propeller for use with a certain engine or type of engine. The pertinent requirements of 6 CFR 04, regarding the functioning of the installed powerplant unit and the performance of the complete airplane, are, of course, applicable whenever a new propeller design is installed. If the propeller model or type is listed on the pertinent airplane specification it has met these latter requirements.

.012 PRODUCTION CERTIFICATE

A 1. GENERAL. Recommended practices requisite for the production of wood and metal propellers under a production certificate are discussed separately below. (See also 6 CFR 01.521). In either case it should be noted that a semi-annual report of the production is required in January and July of each year in accordance with 6 CFR 01.76.

B WOOD PROPELLERS.

1. Due to the stabilized nature of fixed-pitch wood propeller construction the procedure and equipment have evolved to the point where certain minimum standards may be set forth. The following items are intended to present such standards in materials, processes, manufacturing tolerances, and inspection methods.

2. The materials of construction should be of the highest quality obtainable because of the highly stressed condition of a propeller and its relative importance as a primary powerplant item. The following details should be noted:

a. Wood used should be purchased from a reputable lumber company under a detailed specification as to its characteristics. It is recommended that all lumber from which

propeller laminae are to be out be kiln dried to a moisture content of between seven and ten percent. The minimum specific gravity of the various woods (based on oven dry weight and volume) should be as follows:

Birch, sweet or yellow	0.58
Oak, white	0.65
Walnut, black	0.52
Mahogany, African	0.48

Spiral or diagonal grain should have a slope of less than 1 in 10 when measured from the longitudinal axis of the laminae. The wood should be free from checks, shakes, rot, and excessive worm holes. To reduce the effect of internal variations present in all wood, the importance of selecting a high grade of material cannot be over emphasized.

b. Glue used should be of a high quality animal or casein type. Blood albumin glues, marine glues, and the various phenol-aldehyde adhesives are not considered satisfactory due either to their peculiar properties or method of application.

c. Varnish used should be a high quality spar varnish or its equivalent. In any event, the coating used must be transparent to facilitate field inspection for cracks and opened glue joints.

d. Tipping materials should be of a good grade brass, monel metal, stainless steel, or the equivalent. The recommended minimum thickness is 0.022 inches. A linen fabric is frequently applied to the surface for additional strengthening at the tip and for protection against abrasion and splintering. It should be finished with transparent dope or varnish but metal tipping need not be.

3. Processes and methods employed in the fabrication of the propeller shall be those definitely known to yield the best construction. The following sequence of operations and methods employed is presented because, if carefully followed, it will result in an air-worthy product.

a. Laminations should be laid out with the longitudinal axis parallel to the grain of the boards from which they are to be cut. All lumber should stand under shop conditions at least 24 hours to thoroughly adjust itself before working. It has been found satisfactory to either blank out the laminations prior to glueing or to glue up a rectangular block and rough it down to shape. Hub wideners may be incorporated in all but the outer laminae if so shown on the sealed drawing. The widener joint must clear the outer edge of the hub bolt holes by at least one bolt hole diameter and

adjacent joints must be staggered. Spliced laminae will not be permitted in general although certain instances may be allowed on the basis of overspeed whirl tests. Such cases will be considered individually. Laminae thickness may vary from 1/2" to 1" but any further variation should be shown on the sealed drawings. Laminae of the same thickness should be used in a propeller, except for outside ones. After passing inspection the laminae should be planed to thickness on a suitable planer or joiner. Prior to assembly for glueing the laminae should be separated into three classes: light, medium and heavy. Only laminae of one class should be assembled in a single propeller. These should be individually balanced and assembled with the heavy ends of adjacent laminae at opposite ends to facilitate balancing.

b. Glue. Due care should be used in mixing and applying the glue. Casein glue should never be mixed at a speed greater than 120 rpm and the majority of the mixing should be done at half this speed. The complete mixing operation should be accomplished in 20 to 30 minutes. Too rapid stirring beats an excessive amount of air into the mixture, which tends to weaken the glued joint. If lumps are present at the completion of the mixing the batch should be discarded. A dough-type of mixer with a two-speed electric motor is considered preferable. The glue-water proportions for animal glue should be as specified by the manufacturer. The proper spread of glue is about 7 3/4 lbs per 100 square feet of surface when applied to only one face of the joint. With Casein glue a pressure of 150 to 200 p.s.i. should be applied. Slight variations from ordinary room temperatures do not require any important change in assembly time. However, with animal glue there is a definite relationship between temperature and assembly time. For a detailed discussion of this point refer to Trayer, "Wood in Aircraft Construction", pages 103--115. Figure 1 has been made up from this source.

OPTIMUM GLUEING CONDITIONS USING ANIMAL GLUE

Species	Glue-Water proportions by weight.	Approximate Glue Spread	Temperature of Wood	Pressure	Assembly Time (*)
Mahogany	1:2 1/4	7 3/4 lbs per	70°F	150-200 p.s.i.	1/2-1 min.
	1:2 1/4	7 3/4 100 sq ft.	80	150-200	2-5
	1:2 1/4	7 3/4	90	150-200	7-18
Yellow Birch	1:2 1/4	7 3/4	70	200	1
White Oak	1:2 1/4	7 3/4	80	200	3-5
Black Walnut	1:2 1/4	7 3/4	90	200	12-18
White Ash	1:2	7 3/4	70	200	1/2

* Assembly time based on wood pieces being laid together as soon as spread with glue.

FIG. 1

c. Pressing may be accomplished manually by the use of C-clamps or by a jack-press. In any event, the pressure range defined in the preceding paragraph should not be exceeded. The pressing time for both casein and animal glues should be at least five hours, with a greater time desirable. A conditioning period of at least seven days should be allowed after removal from the press or clamps.

d. Shaping. After conditioning, the propeller should be roughed out to within 1/8 inch of the finished surface, either by hand or with a profiling machine. After this operation the propeller should be conditioned for an additional seven days or more at approximately 70°F. and 40% relative humidity.

e. Finishing. The propellers should be carved and worked to a final size using suitable templates and a bubble protractor. Final operations should include a smooth sanding. The propeller should be rigidly mounted for these operations. The change in pitch angle from station to station shall be smooth and true throughout the blade length with no irregularities in contour. A set of metal templates suitably stamped should be available for this stage.

f. Drilling. The hub holes should be drilled with extreme accuracy, using a suitable jig and taking care to insure that the holes are perpendicular to the hub faces.

- g. Tipping. The tipping material should be attached to the leading edge with No. 4 wood screws, 1/2 inch or 3/8 inch long out to 1/2 inch blade thickness. Outboard of this point 3/32 inch diameter brass or copper rivets should be used. The blade should be drilled and countersunk for the screws. The rivet holes should be drilled after the tipping is screwed on. The metal tipping should not be countersunk either for the screws or rivets. The rivet heads and screw heads should be filled with solder and filed down to a smooth surface. The metal tipping should be vented by drilling several holes in the tip after assembly. (Three 0.040 in. diameter holes to a depth of 1/2 in. are recommended.)
- h. Finish. One coat of varnish should be applied prior to, and at least two coats after, tipping. A priming coat of valoil or a paste wood filler may be applied initially. The hub bore should also receive several coats of varnish. In any event the finish coat must be transparent throughout to allow inspection for cracks and opened glue joints.
- i. Horizontal Balance. The propeller should be balanced after shaping and after each successive operation that might affect the balance. Final balance should be accomplished on a rigid knife-edge balancing stand in a room free from air currents. No persistent tendency to rotate from any position on the balance stand should be present.

Horizontal unbalance may be corrected by the application of clear varnish or solder to the light blade. The light blade may be coated with a high grade of clear primer allowing for a finishing coat of clear varnish. After allowing each coat to dry 48 hours, the balance should be checked. Then, as may be necessary, either the required amount of varnish should be removed by carefully sandpapering or an additional coat applied, allowing for the finishing coat of varnish which should be a thin coat of high grade clear spar varnish. The balance should be rechecked and sandpaper or additional varnish applied as may be required to effect final balancing. Only clear finish is permitted.

- j. Vertical unbalance may be corrected by applying putty to the light side of the wood hub at a point on the circumference approximately 90 degrees from the longitudinal centerline of the blades. The putty should be weighed and a brass plate weighing slightly more than the putty should be cut out. The thickness of the plate will be from 1/16 to 1/8 inch depending on the final area, which must be sufficient for the required number of flat head attaching screws. The plate should be formed to fit the shape of the light side of the wood hub, and drilled and countersunk for the required number of screws. The plate should then be

attached and all of the screws tightened. After the plate is finally attached to the propeller, the screws should be secured to the plate by soldering the screw heads. The balance should be checked and all edges of the plate beveled to reduce its weight. The drilling of holes in the propeller and the insertion of lead or other material to assist in balancing will not be permitted.

4. Inspection. An inspection system should be established to accomplish adequate checks on material being used, tolerances on the finished product, and balance. Recommended tolerances and forms are discussed below in Figure 2 and items (a), (b), and (c).

WOOD PROPELLER TOLERANCES

Blade length		$\pm 1/16''$
Blade width	(shank to 24 inch station)	$\pm 3/32''$
	(24 inch station to tip)	$\pm 1/16''$
Blade thickness	(shank to 24 inch station)	$\pm 1/8''$, $-1/16''$
	(24 inch station to tip)	$\pm 3/64''$
Edge alignment		$\pm 1/16''$
Face alignment		$\pm 1/8''$
Template fit	(shank to 24 inch station)	$3/32''$
	(24 inch station to tip)	$1/32''$
Blade angle	(shank to 18 inch station)	$\pm 1.0^\circ$
	(24 inch to 30 inch station)	$\pm 0.5^\circ$
	(36 inch station to tip)	$\pm 0.4^\circ$
Track		$1/16''$
Thickness of hub		$\pm 1/32''$
Diameter of hub		$\pm 3/32''$
Hub bolt holes		$\pm .005''$

FIG. 2

- a. By edge alignment is meant the distances parallel to the respective chords of the sections from the center line of the blade to the leading edges of the cross-sections of the blade at the various stations. By face alignment is meant the distances from the center line of the blade to its thrust or working face as measured perpendicular to the chords of the blade at the various stations.
- b. Blade thickness may be checked with a pair of calipers. The hub bolt holes should be checked with an exact size "go" gage and a 0.010 inch oversize "no-go" gage.

c. A suitable final inspection form should be completed and filed for every propeller produced. Figure 17 on page 39 is a suggested form for this purpose. This form should be signed by some responsible person designated as Chief Inspector by the company. On the back of the form the production tolerances (see Figure 2) should be printed.

C METAL PROPELLERS

1. Because the art of producing an airworthy metal propeller of the various types is highly individualistic and because such production may properly be accomplished on a variety of machinery and equipment, this section will be confined to indicating what is acceptable in the way of manufacturing tolerances and balancing and inspection methods. Forged solid aluminum alloy blades, forged solid steel blades or welded hollow-steel blades retained in a forged steel hub construction have proven acceptable types of construction thus far and will be discussed in order. The workmanship and material of all types should be of a high quality. All blades and hubs should be finished smooth and free from defects, visible scratches, and tool marks. The effect of surface roughness in creating high local stress concentrations and promoting fatigue failure is such as to easily be critical in any design.

2. Forged solid aluminum alloy blades or one piece propellers may be forged solid or machined from a forged billet. Great care should be exercised in securing a high quality of material and a sound forging. It is recommended that a check be made in the physical and chemical properties of each forging or billet used by extracting a test piece and subjecting it to a complete physical and chemical test.

a. For inspection purposes each blade should be etched in a 20% caustic soda solution and cleaned in a 20% nitric acid solution and warm water. The blades should be carefully examined with a three power magnifying glass for the presence of cracks and other defects. Suspected defects should be repeatedly etched until their nature is determined. A crack will appear as a distinct black line. Transverse cracks of any size or description are sufficient cause for rejection provided they cannot be worked out within the tolerance limits as given in 14.012-C2(b) herein. Longitudinal cracks which increase in size as the surface metal is removed are also considered cause for rejection provided they cannot be worked out within the above-mentioned tolerance. Small longitudinal inclusions, if relatively few in number, may be passed at the inspector's discretion. Blades which show excessive amounts

of inclusions, scabbiness, or other abnormal conditions which cannot be worked out within the tolerance limits, must be rejected.

b. Blades of the same design should be interchangeable in all respects. This requirement dictates to a large extent the necessary production tolerances and balancing requirements. The recommended production tolerances for forged aluminum alloy blades are given below in Figures 3 and 4.

ALUMINUM ALLOY BLADE PRODUCTION TOLERANCES

Basic Diameter -- 10 ft. 6 in., or less		
Blade length		$\pm 1/16''$
Blade width	(shank to 24 inch station)	$\pm 3/64''$
	(30 inch station to tip)	$\pm 1/32''$
Blade thickness		$\pm .025''$
Edge alignment		$\pm 1/32''$
Face alignment		$\pm 1/32''$
Template fit	(shank to 24 inch station)	$\pm 1/32''$
	(30 inch station to tip)	$\pm .020''$
Blade angle	(shank to 18 inch station)	$\pm 0.5^\circ$
	(24 inch to 30 inch station)	$\pm 0.25^\circ$
	(36 inch station to tip)	$\pm 0.20^\circ$
Longitudinal location of stations		$\pm 0.015''$

FIG. 3

ALUMINUM ALLOY BLADE PRODUCTION TOLERANCES

Basic Diameter -- over 10 ft. 6 in.		
Blade length		$\pm 1/16''$
Blade width	(shank to 24 inch station)	$\pm 1/16''$
	(30 inch station to tip)	$\pm 1/32''$
Blade thickness	(shank to 24 inch station)	$\pm 0.030''$
	(30 inch station to tip)	$\pm 0.025''$
Edge alignment	(shank to 24 inch station)	$\pm 1/16''$
	(30 inch station to tip)	$\pm 1/32''$
Face alignment	(shank to 24 inch station)	$\pm 1/16''$
	(30 inch station to tip)	$\pm 1/32''$
Template fit	(shank to 24 inch station)	$3/64''$
	(30 inch station to tip)	$0.020''$
Blade angle	(shank to 24 inch station)	$\pm 0.5^\circ$
	(30 inch station to tip)	$\pm 0.25^\circ$
Longitudinal location of stations		$\pm 0.015''$

FIG. 4

Edge and face alignment are defined in 14.012-B 4(a) herein.

c. The interchangeability requirement of the preceding paragraph requires that all blades of the same design balance against each other throughout the entire range of blade angles. This may be accomplished by checking each blade against a master blade or a master cylinder. It is recommended that the balancing equipment for this operation be within a sensitivity of 0.04 inch-pounds in horizontal balance and 0.2 inch-pounds in vertical balance. The finished propeller should balance both horizontally and vertically at both 0 and 90 degrees to the plane of rotation without showing a persistent tendency to rotate in any direction. Final balancing should be done on a knife-edge balancing stand in an enclosed room which is free from air currents. Horizontal balance may be corrected by drilling a concentric hole in the base of the blade which hole must conform with the specifications of Figure 5. Vertical balance may be corrected by drilling an eccentric hole not greater than $3/8$ inch in diameter to a depth not exceeding that specified in Figure 5. The outer edge of this hole shall not be closer than $1/4$ inch to the nearest external blade surface and not more than one eccentric hole should be drilled per blade. These holes may be left open or filled with lead. Leaded holes should be corked.

SIZE AND DEPTH OF BALANCING HOLES

Shank Size	Maximum con- centric hole diameter	Maximum con- centric hole depth	Maximum eccentric hole depth. (3/8 in. max. dia.)
00	7/16 inches	2 1/2 inches	2 1/4 inches
0-V2	19/32	3 3/8	3
1/2	5/8	3 5/8	3 1/2
1	3/4	4 1/4	4
1 1/2	13/16	4 7/8	4 1/2
2	7/8	5 1/2	5
3	31/32	6 1/8	6

FIG. 5

As an alternative to drilling the two holes mentioned above, a single eccentric hole having a diameter and depth conforming to the concentric hole dimension given in Fig. 5 may be drilled and filled with lead. The outer edge of this hole should not be closer than one inch to the nearest external blade surface. The ends of all balancing holes should be finished with a full size drill having a spherical end to eliminate corners. The sharp edges of the hole should be removed by a 1/32 inch chamfer. Blades having special hub ends which are designed for use in controllable pitch propellers should not be drilled with this eccentric balancing hole.

3. Forged solid steel blades may be forged solid or machined from a forged or rolled billet of suitable alloy steel. A check should be made of the physical properties by taking a test specimen from each and subjecting it to complete physical tests after heat treating. An ample check should also be made of the chemical content of the material.

a. All blades should be inspected by the wet magnaflux process for discontinuities, cracks, and other defects. Any unsatisfactory indications which cannot be worked out within the tolerance limit below should be sufficient cause for rejection. The magnaflux inspection should be under the direct supervision of highly-experienced personnel.

b. Acceptable production tolerances for solid steel blades are given in Figure 6.

SOLID STEEL BLADE PRODUCTION TOLERANCES

Blade length		$\pm 1/16''$
Blade width	(from shank to 24 in. station)	$\pm 1/16''$
	(from 24 in. station to tip)	$\pm 1/32''$
Blade thickness	(from shank to 24 in. station)	$\pm 0.030''$
	(from 24 in. station to tip)	$\pm 0.025''$
Edge alignment	(from shank to 24 in. station)	$\pm 1/16''$
	(from 24 in. station to tip)	$\pm 1/32''$
Face alignment	(from shank to 24 in. station)	$\pm 1/16''$
	(from 24 in. station to tip)	$\pm 1/32''$
Template fit	(from shank to 24 in. station)	$3/64$
	(from 24 in. station to tip)	$0.020''$
Blade angle	(from shank to 24 in. station)	$\pm 0.50^\circ$
	(from 24 in. station to tip)	$\pm 0.25^\circ$
Longitudinal location of stations		$\pm 0.015''$

FIG. 6

Edge and face alignment are defined in 14.012-B 4(a) herein.

c. Blades of the same design should be interchangeable in all respects. They should, therefore, balance against each other throughout the operating range of blade angles. This may be accomplished by checking each blade against a master blade or cylinder. The balancing apparatus should have a sensitivity of approximately 0.04 inch-pounds in horizontal balance and 0.2 inch-pounds in vertical balance and should be used in a room free from air currents. The blades should balance both horizontally and vertically when set at both 0 and 90 degrees to the plane of rotation. Inserts or balancing plugs used in the blade shanks for the correction of unbalanced conditions will be considered individually. In all cases they should be shown on the sealed drawing.

4. Welded hollow-steel blades should be welded up from suitable sheets or strips of steel alloy. The material used in this type blade should be heat-treated to obtain the following minimum physical properties:

Ultimate tensile strength	125,000 p.s.i.
Proportional limit	65,000 p.s.i.
Elongation	12%

Blades of this type should be made from blanking dies, forming dies, welding jigs, heat-treat jigs and similar production tools with a minimum of filing, grinding, wedging, or other hand operations. A standard tension test sample should be cut from each sheet of steel used and subjected to

physical tests to determine the above properties. Sufficient chemical analyses should also be run to determine the chemical properties of the material and to assure a uniform composition.

a. All blades should be inspected at various times during the production process by means of the wet magnaflux process. A frequent number of inspections will be found desirable in order to eliminate a large number of rejections in the final stage of production. Any pronounced magnaflux indications which cannot be eliminated by removing a maximum of 10% of the plate thickness at this stage are considered sufficient cause for rejection. The magnaflux inspections should be under the direct supervision of highly-experienced personnel. Adequate visual inspection should also be accomplished to detect incomplete welds, concentration of welding material, and the abrupt termination of a weld in such a manner as to constitute a stress concentration point.

b. Recommended production tolerances for hollow-steel blades are given in Figure 7.

HOLLOW STEEL BLADE PRODUCTION TOLERANCES

Blade length		+ 1/16"
Blade width	(from shank to 24 inch station)	± 1/16"
	(from 24 inch station to tip)	± 3/64"
Blade thickness	(Maximum ordinate)	± 0.045"
Edge alignment		± 1/8"
Face alignment		± 0.045"
Template fit	(from shank to 24 inch station)	1/16"
	(from 24 inch station to tip)	0.045"
Blade angle	(from shank to 24 inch station)	± 1.0°
	(from 24 inch station to tip)	± 0.5°
Longitudinal location of stations		± 1/16"

FIG. 7

Plate thickness should be held to the following limits:

0.375 to 0.565 thickness	-0.004, +0.015
0.156 to 0.375 thickness	-0.003, +0.010
0.060 to 0.156 thickness	-0.002, +0.005

Edge and face alignment are defined in 14.012-B 4(a) herein.
The surfaces and edges between stations should be of fair contour.

5. Forged steel hubs should be forged in a die from medium carbon, chrome-vanadium, or chrome-nickel-steel bars or the equivalent. Chrome-vanadium steel hubs should have a Brinell hardness of 295 ± 20 (10 mm. ball, 3000kg) in the center of the thickest portion. Chrome-nickel steel hubs should correspondingly have a Brinell hardness of 305 ± 20 . Either material should show at least the following minimum physical properties:

Ultimate tensile strength	135,000 p.s.i.
Yield strength	115,000 p.s.i.
Elongation	15%
Reduction in area	50%

Suitable test specimens should be taken from each hub forging to check these physical properties. Sufficient chemical analyses should also be run to determine the chemical properties of the material and to assure a uniform composition. One or more forgings from each new die should be examined for the proper grain flow.

a. All hubs should be inspected by means of the wet magnaflux process. Any pronounced magnaflux indications which cannot be eliminated within the tolerance limit of the design are considered sufficient cause for rejection of the part. The magnaflux inspection should be made under the direct supervision of highly-experienced personnel.

b. There are no general recommended production tolerances for forged steel hubs. Under 14.1-C 5(b) herein are given the recommended dimensions and tolerances for detachable-blade non-controllable propeller hubs. Recommended dimensions and tolerances for that portion of the controllable hub which mates with the engine shaft are given in 14.1-C 5(d) herein.

c. The correctly balanced hub should stand at any angle in the balancing apparatus without displaying a persistent tendency to move in any direction. In order to obtain final balance of the hub, metal may be removed from the portions of the hub where a surplus has been left for balancing purposes, such as shown in Figure 8. The tolerance limit must however not be exceeded in any case.

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HUB MATERIAL REMOVABLE FOR BALANCING

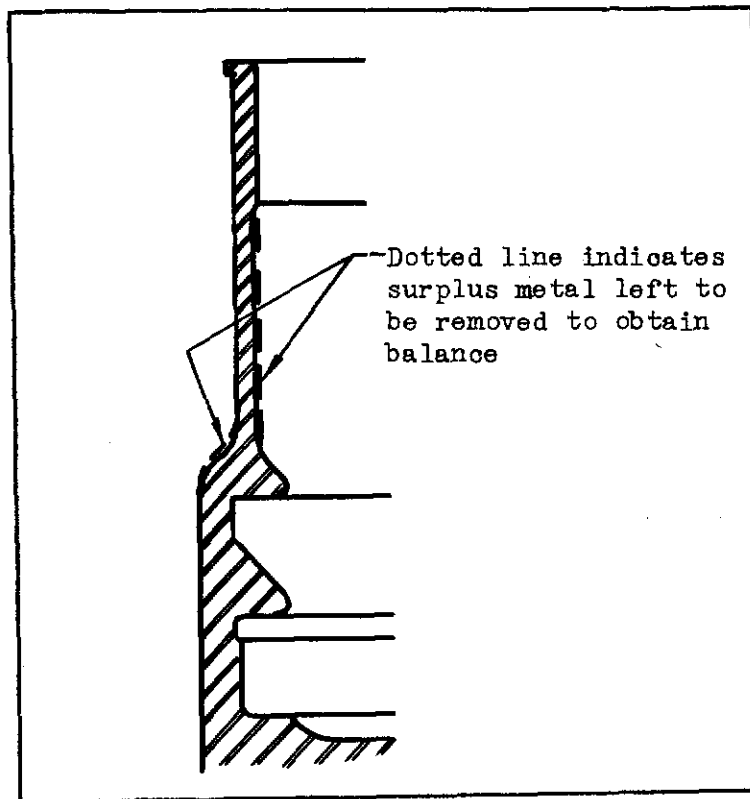


FIG. 8

d. Hub holes, threads and splines should be checked with suitable "go" and "no-go" gages made up on the basis of the allowable manufacturing tolerances.

.013 DEVIATIONS

1. The term unconventional, as used in 6 CFR 14.013, refers to deviations from the conventional with respect to general design and design details. Materials and types of construction other than those mentioned herein are considered unconventional and applications should accordingly be made to the Authority for special rulings covering the design. If there exists any doubt in the mind of the designer as to whether his design is conventional or not, the entire design should be discussed prior to making active preparations for a test program.

.02 HUBS AND BLADES

1. When propeller hubs and blades are interchangeable they are certificated as separate units and this procedure requires the submittal of a complete set of data both for the propeller blade and hub as these data are filed separately.

.03 TESTING FACILITIES

1. It is necessary that the manufacturer conduct all propeller tests and supply or arrange for the proper testing facilities. This normally requires the following equipment:

- a. A new engine (or one in good repair) of the type for which certification of the propeller is desired. If it has not been overhauled recently a top inspection or overhaul may be warranted.
- b. A suitable engine mount.
- c. An accurate tachometer, which should be calibrated before and after testing and checked with a stop watch and revolution-counter during testing.
- d. A suitable manifold pressure gage if the test is not run at full throttle. (Not required for fixed-pitch wood propeller tests)
- e. Sufficient vibration equipment to ascertain beyond reasonable doubt that the propeller will not encounter dangerous resonance conditions in operation. (Necessary only in the case of metal propellers.) Such equipment should preferably consist of a suitable gigo to conduct static vibration tests; and suitable vibration stress pick-ups and recorders*, the former to be mounted on the blades and used to record the vibration stresses during operation; a suitable torsigraph to determine the torsional characteristics of the propeller-crankshaft system; and suitable linear pick-ups to determine the motion of the engine in space.

* Thus far one of the most effective pieces of apparatus has been found to be carbon-strip strain gages connected through slip-rings to a 12 volt D.C. source with a resistor, condenser, amplifier and oscillograph in the hook-up. For additional information on this type of apparatus refer to the Journal of the Aeronautical Sciences, Vol. 5, No. 2, pp. 37-52: "Propellers for Aircraft Engines of High Power Output" by F. W. Caldwell.

.05 PROPELLER OPERATION LIMITS

1. Upon completion of the necessary testing the propeller is certificated for a specified horsepower, rpm, and engine bore limit with a certain diameter and pitch range. Due to the difference in vibration characteristics with different crankshaft systems and gear ratios it has recently been found necessary to supplement these general factors with a qualifying statement as to the specific engine or series of engines for which operation is certificated. Unless definitely stated to the contrary the propeller is assigned a take-off (one minute) operation limit of 10% in excess of the maximum, except take-off limit in power and in speed. Fixed-pitch wood propellers are normally certificated only for a horsepower and rpm with no further qualifications other than diameter and pitch. Due to the type of testing employed (see 14.22 herein) the horsepower is often an approximation with the result that the propeller is essentially certificated for operation not in excess of a given rpm.

.06 PROPELLER IDENTIFICATION DATA

1. In addition to the data specified in 6 CFR 14.06 some manufacturers have found it desirable to stamp the approval number on the propeller. This has the advantage of giving the inspector or owner a basic reference to the current specification for the operation limits applicable. It is suggested that this item be added but it may not be substituted for the other required data.

.1 DESIGN REQUIREMENTS

A GENERAL

1. Design requirements and recommendations will be discussed separately for wood and metal propellers. 6 CFR 14.10, 14.11, 14.12, and 14.13 are covered in this general discussion.

B WOOD PROPELLERS

1. The matter of recommended finishes, materials, tolerances, hub wideners and balancing has previously been discussed for this type of propeller under 14.012-B herein. Problems of a design nature will be considered under this topic as quantitatively as possible.

2. Blades should be laid out with a faired contour in planform and thickness. Abrupt changes in cross-section are to be avoided.

Curves of maximum thickness and of minor and major moments of inertia versus radius should be developed and submitted to check this point on new designs. The center of gravity of the blade sections is preferably a straight line or nearly so in the planform view. This line should have a slight forward tilt to relieve the aerodynamic load on the blade. The condition of take-off and climb probably subjects this type of propeller to the most severe steady loads due to the small relieving action of the centrifugal force at the low revolution speeds combined with the high thrust loadings.

3. Blade tip sections should be designed with great care. In general, thin tip sections have caused trouble even in wood propellers and are to be avoided. The designer might well use a slightly thicker tip section at the expense of some propulsive efficiency. Markedly thin tips with their accompanying flexibility tend to promote flutter and resonance conditions. It does not follow that a thick tip insures against flutter and resonance, however, a thick tip on a well-designed blade is preferable structurally if not aerodynamically.

4. Some trouble has been experienced with blade tipping due to poor location of the attaching screws and rivets. These attachments should not be in a straight line parallel to the grain of the wood as this promotes cracking along sections in line with the screws.

5. The finish of the wood propeller should be transparent as required in 6 CFR 14.13 and discussed in 14.012-B3 (h) herein. This is to facilitate inspection for cracks and opened glue joints at the time of the annual inspection.

6. To promote a standardization of propeller hub attachments it is recommended that steel hubs for wood propellers be designed in conjunction with the engine shaft according to the SAE standard dimensions. As this type of hub is ordinarily designed, manufactured and certificated as an engine part, it is only mentioned here in passing. The front flange should preferably be splined to the hub proper in all except designs for 50 hp. or less. This matter and other pertinent design data will be discussed under boss design in 14.1-B 7 herein.

7. The extensive service use of the fixed pitch wood propeller has made it possible to investigate portions for quantitative design criteria. The following analysis of this type propeller has been made from the viewpoint of experience.

a. The boss (or hub portion) is stressed chiefly by the steady air loads and centrifugal loads with the engine torque impulses superimposed. The torque impulses prove

the most severe for the boss, and service failures give a definite indication of this in burned and elongated bolt holes. Once these holes are elongated and the propeller starts to rock on its hub the bolts are subjected to abrupt eccentric loads which tend to shear the bolt heads.

b. For the majority of designs the rear flange of the steel hub is integral with the splined portion which mates with the crankshaft, while the front flange may be splined to the hub or simply serve as a collar. Assuming the engine torque to be resisted only by the bearing area of the hub bolts and neglecting the effect of friction between the wood and metal surfaces*, it is possible to calculate the "propeller resisting torque" for a specific design. This must be modified for some designs to account for the added strength of splining the front flange. If the hub bolts were rigidly supported at each end their bearing strength would increase 100% over the cantilever type. Because of the varying amounts of play in the splined front flange this 100% increase has been arbitrarily reduced to 25%.

c. The "propeller resisting torque" may be expressed in a formula as follows:

$$T_p = F_b A R f$$

where T_p = propeller resisting torque (ft.lbs.)
 F_b = elastic limit allowable crushing stress (p.s.i.)
 A = total hub bolt bearing area (sq.in.)
 R = bolt circle radius (ft.)
 f = front flange factor (1.25 for splined flange,
 1.00 for floating flange.)

d. T_p has been plotted against rated engine torque multiplied by the bore in Figure 9 for representative designs. 790 p.s.i. has been used for F_b for birch. (See Trayer, "Wood in Aircraft Construction", pp. 212-218.) Torque multiplied by the bore was used as a good criterion of the severity of the torque impulses from the engine.

e. The straight line in Figure 9 is a recommended minimum safe value for use in the conventional steel hub and wood propeller design. It may be expressed by the equation:

$$T_p = 1.4 (T_E B) + 350$$

where T_E = rated engine torque (ft.lbs.)
 B = cylinder bore (inches)

* Neglected for several reasons; first, the actual amount of friction will vary considerably with the humidity of the air and tightness of the bolts; second, service failures have indicated the number and size of hub bolts rather than the size of the flanges to be critical.

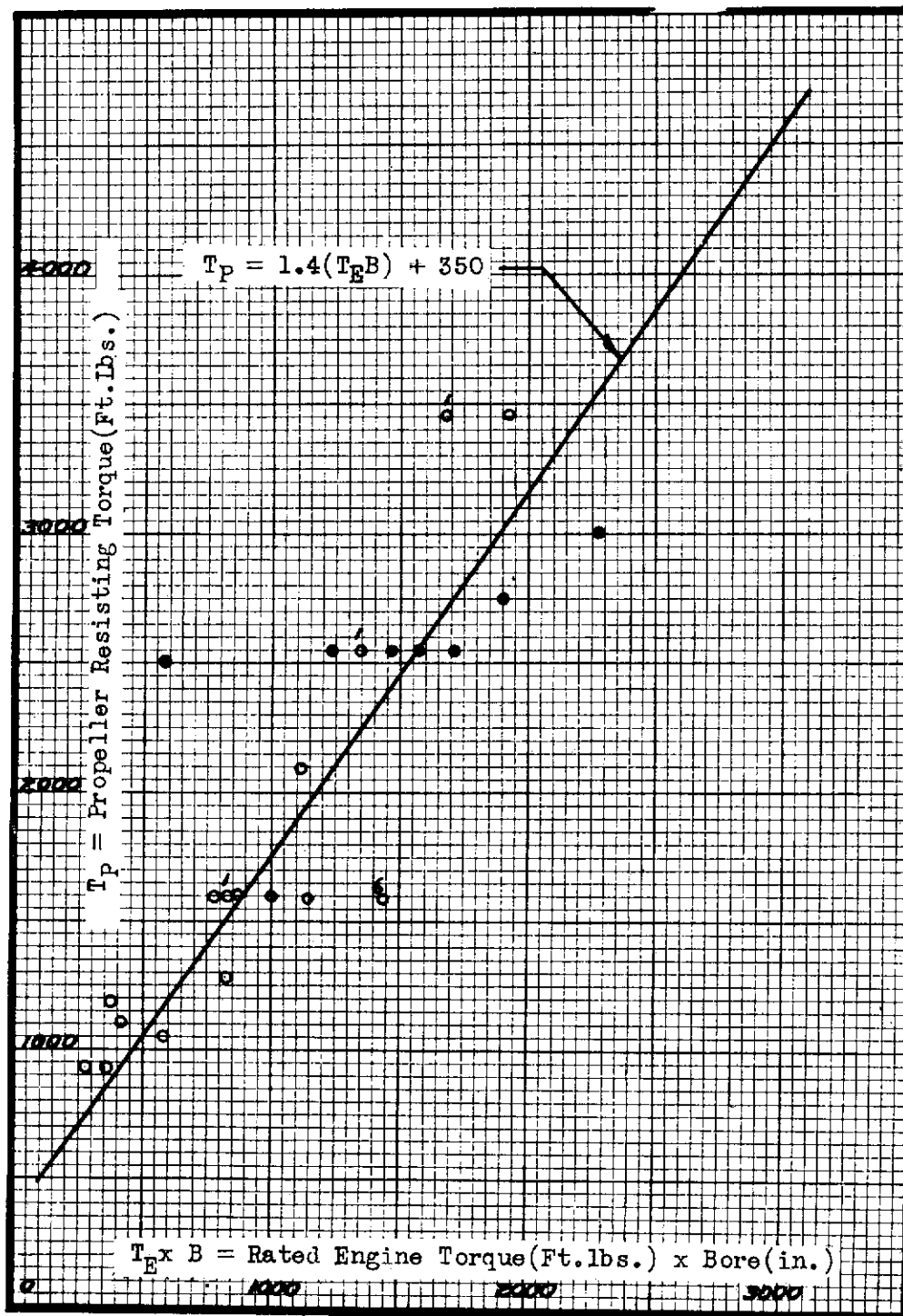


FIG. 9 WOOD PROPELLER BOSS STRENGTH CRITERIA

f. Each circle in Figure 9 represents a propeller and hub combination. The solid circles are those designs with a splined front flange and the open circles are those with a floating front flange. The number above the circle indicates the number of failures reported. In all cases the most highly stressed design is shown.

g. The three isolated cases of single failure may be disregarded since many identical designs are satisfactory. Faulty maintenance, such as loose hub bolts, may have been a contributing cause. However, the series of six failures for the one design is a definite indication of an unsafe condition and this particular design had to be completely changed before satisfactory results were obtained. For design purposes the material presented in Figure 9 and the equation in 14.1-B 7(e) herein should determine the number, size, and disposition of the hub bolts.

h. To further aid in determining the boss dimensions it is recommended that the length / diameter ratio of the hub bolts should not exceed eleven and that the clearance from the center of the bolts to the outer surface of the boss be a minimum of $2 \frac{1}{2}$ times the bolt diameter. Center to center bolt spacing on the bolt circle should be $5 \frac{1}{2}$ times the bolt diameter (minimum) and the center of the hub bolts should clear the center bore by 3 times the bolt diameter.

i. In considering design improvements it is well to recognize the critical portions of the design and the possibilities of relieving them. The highest local value of bearing stress is experienced in the wood at the hub bolts where they enter the rear flange of the hub and where the load deflection is least.

j. To relieve this portion of the material some designs incorporate a bushing at the rear flange to increase the bearing area of the bolts at this point.

7. Plastic wood propellers composed of compressed impregnated wood at the shank and encased in a reinforced cellulose-acetate covering have only recently been introduced in this country, hence they can only be noted in passing. Since this type of propeller blade is constructed with a steel shank casing, the hub design recommendations in 14.1-C herein should be adhered to wherever possible.

8. The subject of model designation is discussed here because the designer usually assigns such a designation. Although there is some precedent to the contrary, it is not considered advisable to approve a pitch range under one model designation. For the purposes of field identification it is essential that each pitch be assigned

a distinguishing dash number. For example, model 89B could be designated as 89B-48, 89B-52 and 89B-56 referring to pitches of 48, 52 and 56 inches respectively. The "89" as used could refer to the diameter in inches and "B" to the basic airfoil section. (See also 14.4-1 herein.)

C METAL PROPELLERS

The wide variation in metal propeller design, both in type and material of construction makes it impossible to advance many quantitative design criteria. The recommended tolerances and balancing methods have been given in 14.012-C herein. The following discussion will of necessity be somewhat generalized but specific recommendation is made whenever possible.

1. Blades of this type should conform to 6 CFR 14.11. The contour should be faired with respect to the planform. Abrupt changes in cross-section are to be avoided. Curves of maximum thickness and of minor and major moments of inertia versus radius may be necessary to check new designs. The center of gravity of the blade sections for controllable pitch propellers should lie on, or nearly on, a straight line along the axis of rotation. This line should have a slight forward tilt to relieve the aerodynamic loading of the blade. The blade fairing should avoid abrupt changes and the shank should be designed with this in mind. When the design incorporates an abrupt change of section, as in the butt-end attaching portion, as large a fillet as possible is recommended to reduce stress concentration at that point. Neglect of this has been a source of trouble in many designs.

2. All surfaces subjected to wear and corrosion should be suitably plated for protection against both. Cadmium has proven satisfactory as a steel hub plating with zinc and chromium among the possible alternatives. Cadmium has a somewhat higher salt water spray resistance than zinc in thin coatings (0.010 in.) but zinc plating is slightly superior to cadmium when exposed to air containing sulphur (city atmosphere). Both cadmium and chromium plated steel blades have given good wearing qualities. Aluminum alloy blades ordinarily have no protective coating but a chromic-acid anodic treatment increases their salt water corrosion resistance.

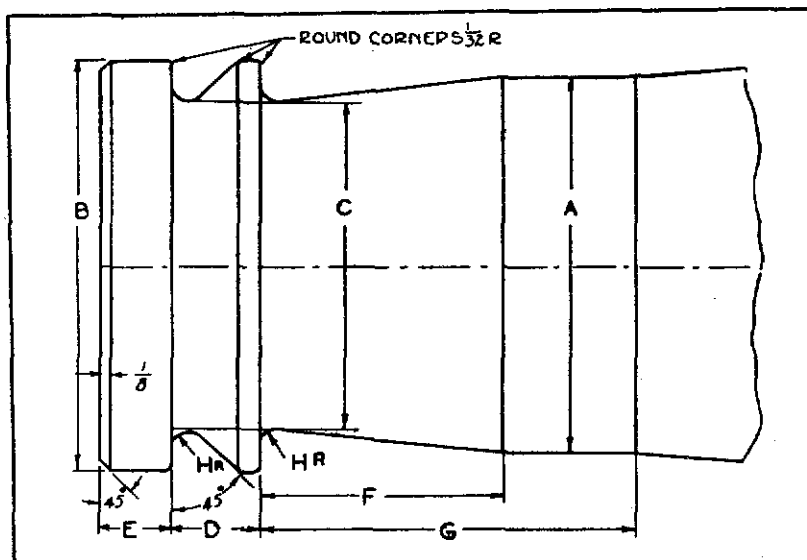
3. Metal propellers are inherently susceptible to resonance conditions and every effort should be made in the design to avoid such a condition in the operating range. All parts should be designed to minimize the effect of vibration upon their operation. This applies to the control mechanism as well as to the hub and blade structure. The control mechanism should be so designed

that a failure will not affect the functioning of the propeller other than to convert it into a fixed pitch propeller. Positive stops should be provided in the hub control mechanism so that designated low-pitch and high-pitch blade angles cannot be exceeded.

4. Blade tip sections should be designed with great care. Thin tip sections have caused trouble in metal blades and extreme thinness is to be avoided because the accompanying flexibility tends to promote resonance conditions. It does not follow that a thick tip insures against resonance, but a thick tip on a well-designed blade is preferable structurally if not aerodynamically.

5. In order to facilitate the interchangeability of parts it is recommended that the propeller design conform as far as possible to Army and Navy or SAE standards. The following dimensions are included for this purpose:

a. Blade and standards are given in Figure 10 and the accompanying table for detachable forged aluminum alloy blades. The fillet radii indicated should not be decreased in any case. It should be understood that this table does not define all possible sizes and that intermediate and larger sizes should be developed as the need becomes apparent. The horsepower is merely listed as a guide to show some of the usage of various size shanks. The values listed cannot be solely used to substantiate the airworthiness of an application for certification.



Usual HP per Blade Range	Blade End No.	+ .000 A - .003	+ .000 B - .003	C ± .010	+ .002 D - .000	E ± .010	F ± .050	+ .06 G - .00	H
0-25	00	2.250	2.495	2.000	0.500	0.4375	1.312	2.187	3/32
25-60	0	3.000	3.245	2.625	0.6875	0.562	1.687	2.937	1/8
60-100	1/2	3.4375	3.745	3.000	0.7812	0.6562	2.000	3.375	1/8
100-250	1	3.875	4.245	3.375	0.875	0.750	2.375	3.750	5/32
250-300	1 1/2	4.1875	4.620	3.6875	1.0625	0.875	2.6875	4.187	5/32
300-400	2	4.500	4.995	3.875	1.250	1.000	3.125	4.625	5/32
400-500	3	5.000	5.620	4.312	1.375	1.125	3.438	5.125	3/16

FIG. 10 - STANDARD ENDS OF DETACHABLE FORGED ALUMINUM ALLOYS BLADES.

b. Standard forged steel hub dimensions for the detachable aluminum alloy blade type are given in Figures 11 and 12.

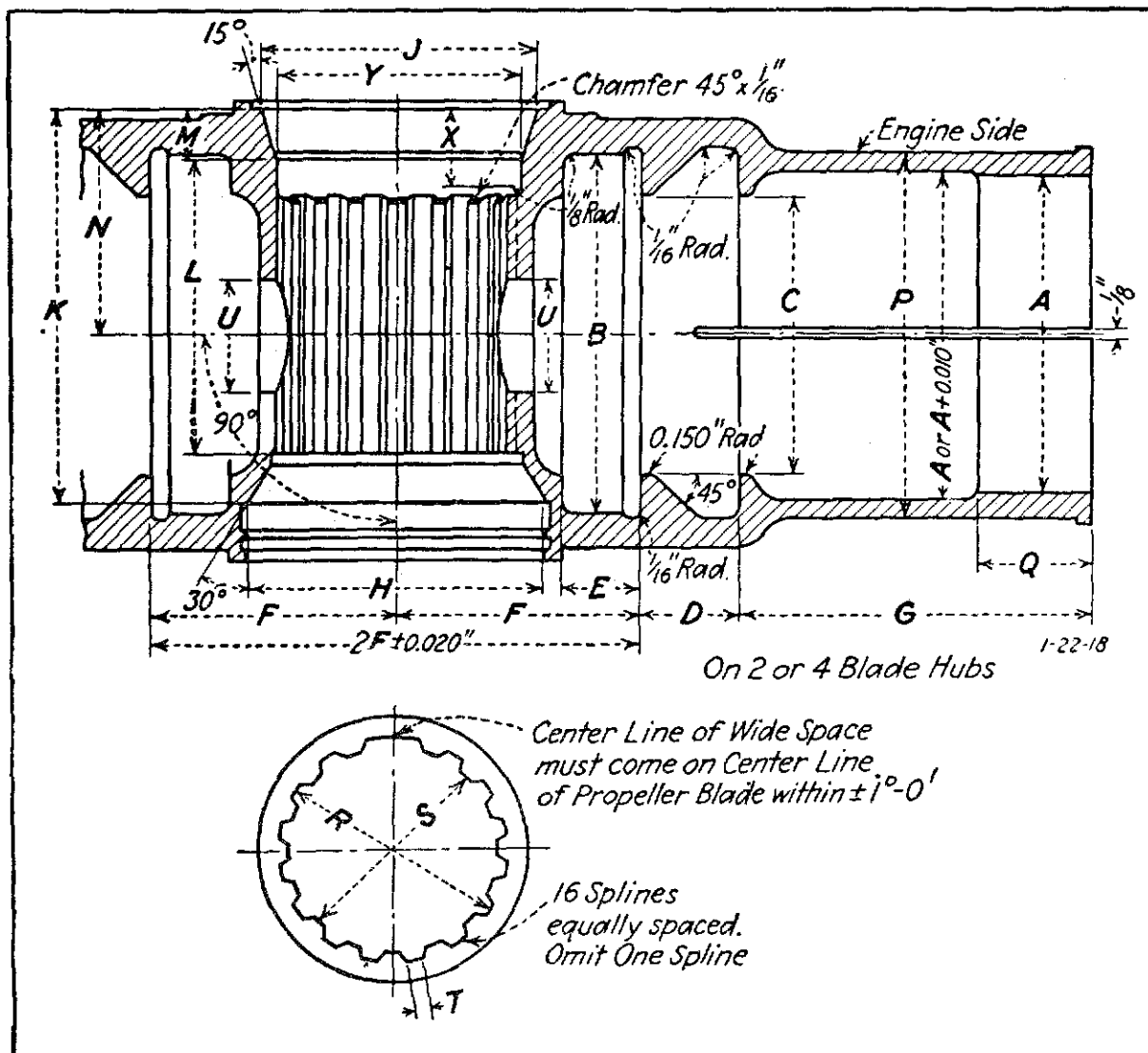


FIG. 11 - DETACHABLE ALUMINUM-ALLOY BLADE TYPE,
FORGED STEEL HUB DIMENSIONS.

Blade No.	1	1	1½	2	1	1½	2	2
Hub. No.	20	30	30	30	40	40	40	50
A ¹ +0.003 -0.000	3.878	3.878	4.190	4.503	3.878	4.190	4.503	4.503
B ¹ +0.002 -0.000	4.247	4.247	4.622	4.997	4.247	4.622	4.997	4.997
C +0.010 -0.000	3.437	3.437	3.750	3.937	3.437	3.750	3.937	3.937
D +0.002 -0.000	0.875	0.875	1.062	1.250	0.875	1.062	1.250	1.250
E	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{11}{16}$
F ²	2.375	2.375	2.500	2.812	2.750	2.937	3.187	3.500
G	$3\frac{3}{4}$	$3\frac{3}{4}$	$4\frac{3}{16}$	$4\frac{5}{8}$	$3\frac{3}{4}$	$4\frac{3}{16}$	$4\frac{5}{8}$	$4\frac{5}{8}$
H +0.000	3.125	3.187	3.187	3.187	3.875	3.875	3.875	4.5625
J +0.000 -0.005	2.875	3.187	3.187	3.187	3.625	3.625	3.625	4.625
K	$5\frac{1}{4}$	$5\frac{19}{32}$	$5\frac{19}{32}$	$5\frac{19}{32}$	$5\frac{1}{4}$	$5\frac{1}{4}$	$5\frac{1}{4}$	$5\frac{13}{16}$
K (Ext'd.)	$6\frac{1}{4}$	$6\frac{21}{32}$	$6\frac{21}{32}$	$6\frac{21}{32}$	$6\frac{19}{32}$	$6\frac{19}{32}$	$6\frac{19}{32}$	$6\frac{23}{32}$
L	4	$4\frac{3}{8}$	$4\frac{3}{8}$	$4\frac{3}{8}$	4	4	4	$4\frac{11}{32}$
L (Ext'd.)	$5\frac{21}{32}$	$6\frac{3}{32}$	$6\frac{3}{32}$	$6\frac{3}{32}$	6	6	6	$6\frac{1}{8}$
M	$\frac{21}{32}$	$\frac{21}{32}$	$\frac{21}{32}$	$\frac{21}{32}$	$\frac{21}{32}$	$\frac{21}{32}$	$\frac{21}{32}$	$\frac{13}{16}$
N	$2\frac{5}{8}$	$2\frac{13}{16}$	$3\frac{1}{16}$	$3\frac{1}{8}$	$2\frac{15}{16}$	$2\frac{13}{16}$	3	3
P	$4\frac{1}{4}$	$4\frac{1}{4}$	$4\frac{5}{8}$	5	$4\frac{1}{4}$	$4\frac{5}{8}$	5	5
Q	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{5}{8}$
R +0.005 -0.002	2.383	2.633	2.633	2.633	3.133	3.133	3.133	3.812
S +0.005 -0.002	2.164	2.414	2.414	2.414	2.881	2.881	2.881	3.562
T ±0.001	0.233	0.259	0.259	0.259	0.306	0.306	0.306	0.377
X	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$1\frac{1}{4}$
X (Ext'd.)	$2\frac{3}{16}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{17}{32}$	$2\frac{17}{32}$	$2\frac{17}{32}$	$2\frac{5}{16}$
Y	$2\frac{13}{32}$	$2\frac{21}{32}$	$2\frac{21}{32}$	$2\frac{21}{32}$	$3\frac{5}{32}$	$3\frac{5}{32}$	$3\frac{5}{32}$	$3\frac{27}{32}$

¹ The center line of A and B shall lie within 0.002 in. of a plane perpendicular to the crankshaft bore center line. The center lines of A and B shall come within 0.002 in. of intersecting the crankshaft bore center line. The limits on the 90 deg. dimension is plus or minus 0 deg. to 1 min. The A and B bores shall be concentric with each other within 0.002 in. The hole U may be omitted at the discretion of the manufacturer.

² Shoulders located by F must be equidistant from center line of hub within 0.002 in. for perfect balance. Finish tolerances are ±0.010 in. unless otherwise specified.

FIG. 12 - FORGED STEEL HUB DIMENSIONS
(Refer to Fig. 11)

c. Standard dimensions for detachable hollow steel blade ends are given in Figure 13. It is recommended that blades of this type be sealed airtight and no vent holes drilled in the tip.

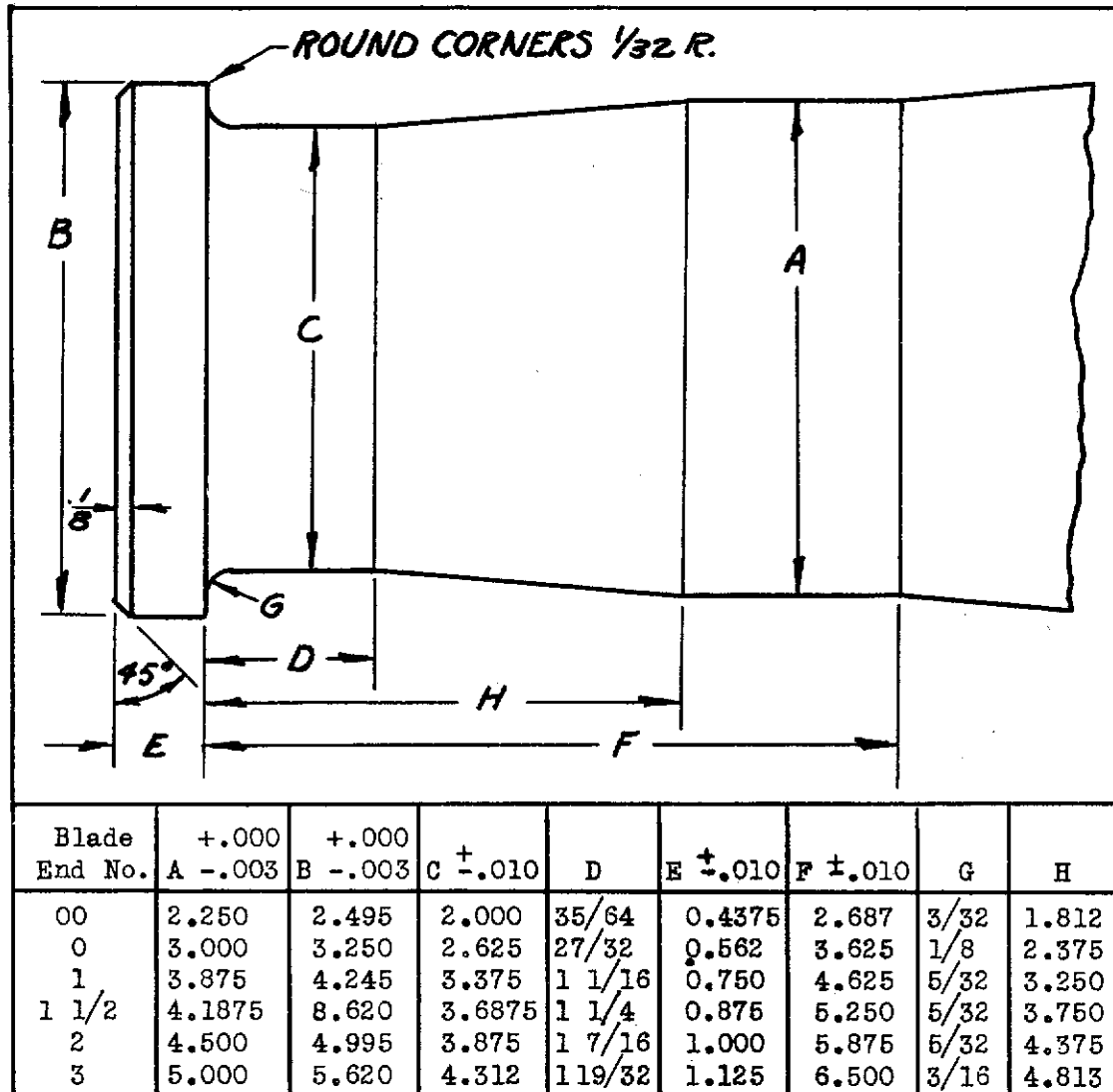


FIG. 13 - HOLLOW STEEL BLADE END DIMENSIONS.

d. Standard dimensions and dimensional tolerances are shown in Figures 14 and 15 for that portion of the hub of controllable propellers which mates with the engine shaft.

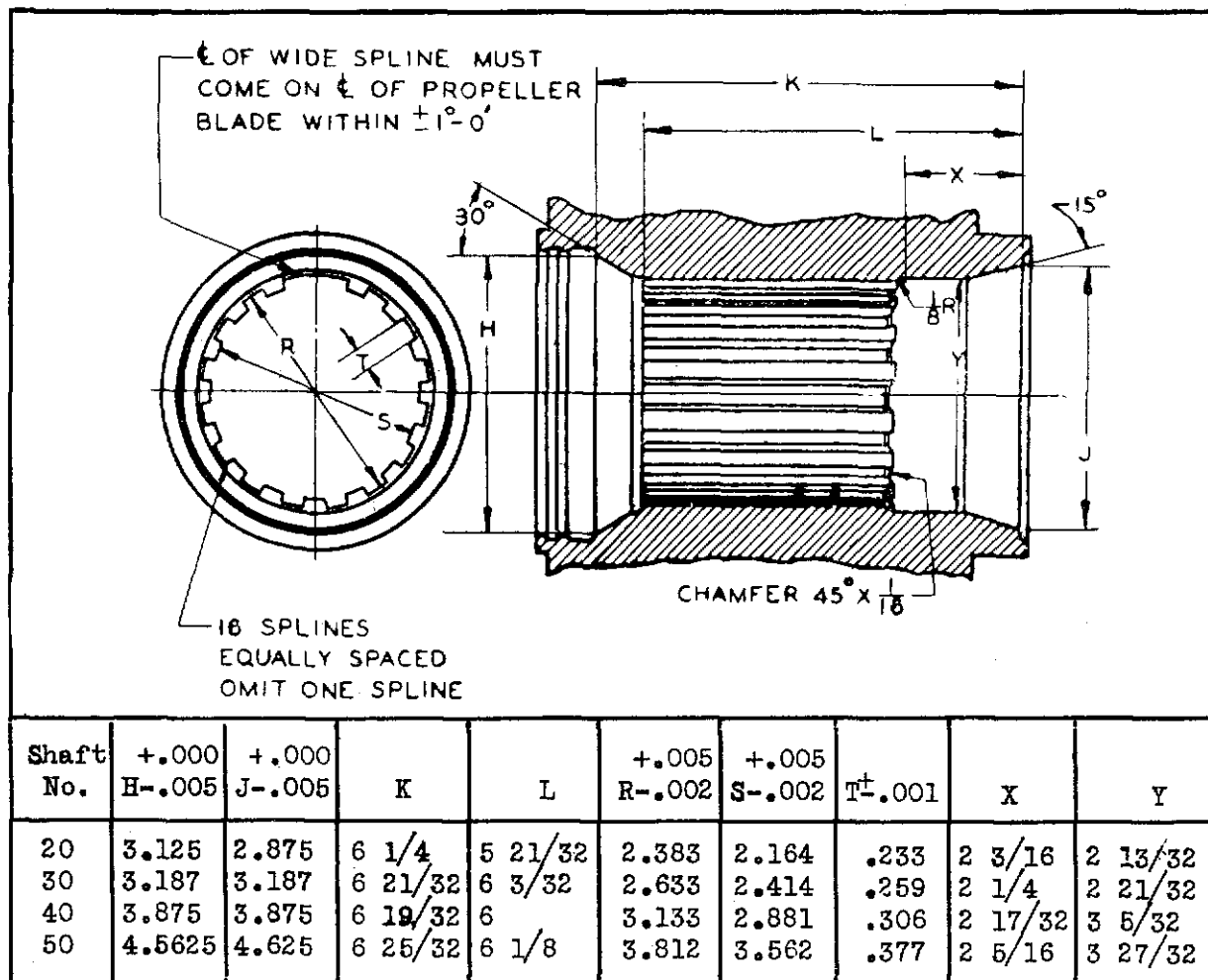
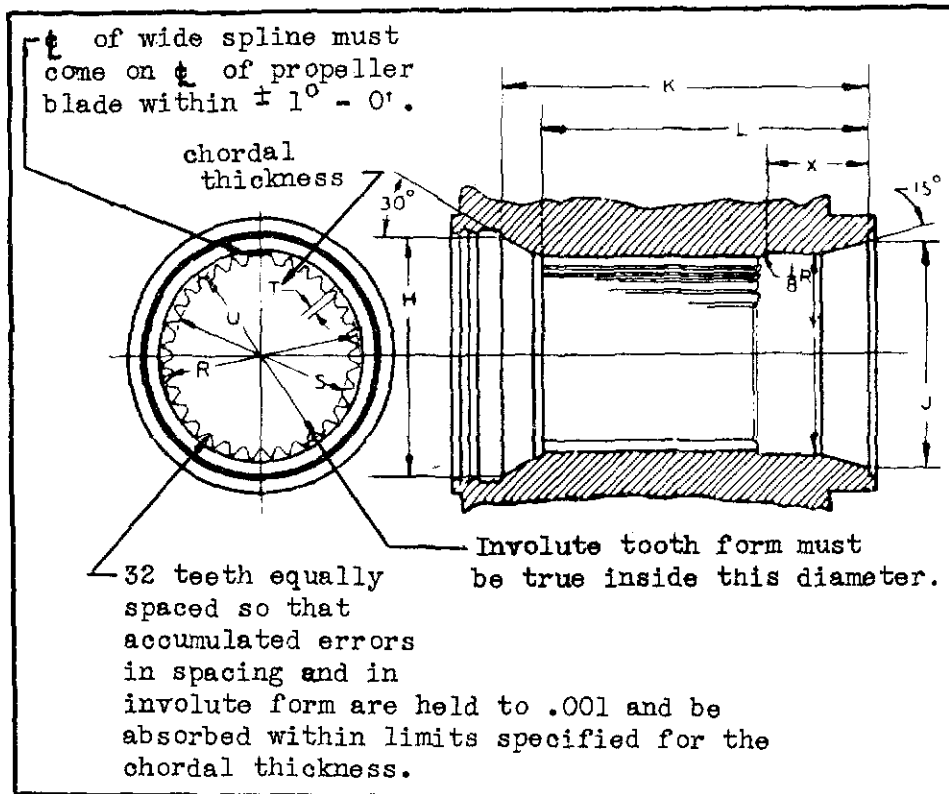


FIG. 14 - CONTROLLABLE PROPELLER HUBS (16 SPLINE).



Shaft No.	+ .000 H - .005	+ .000 J - .005	K	L	+ .005 R - .002	+ .005 S - .002	+ .001 T - .000	U min.	X	Y
60	5.562	5.500	8 1/16	7 1/4	4.8014	4.4464	.2243	4.696	3 5/32	4 27/32

FIG. 15 - CONTROLLABLE PROPELLER HUBS (32 TEETH).

.2 COMMERCIAL PROPELLERS

.20 DATA REQUIRED

- .200 1. The application for a propeller type certificate should be submitted on form CAA 01-9 supplemented by form CAA 14-1. The latter form should enumerate all the engines for which the propeller is designed. If a production certificate is also desired, form CAA 01-10 should be submitted. This form need only be submitted once for each general type, i.e., fixed-pitch, wood, etc., propeller.
- .201 1. Drawings submitted should be complete in all important dimensions, specifications and identification data. The minimum essential details of a propeller drawing should incorporate the following information:
- a. Title block details. (Locate in lower right-hand corner.)
 - (1) Company name and address.
 - (2) Model or identifying number of propeller or part.
 - (3) Date of drawing.
 - (4) Initials of draftsman and checker.
 - (5) All drawing change letters with date of change and description thereof.
 - b. Boss dimensions for fixed-pitch wood propeller.
 - (1) Diameter of engine shaft bore.
 - (2) Diameter of bolt hole circle.
 - (3) Size and location of bolt holes.
 - (4) Diameter and thickness of boss.
 - (5) Cross-section of boss showing location of hub widenings, if used.
 - c. Blade dimensions and details.
 - (1) Side elevation not dimensioned but with the line of centers of gravity.
 - (2) Plan view with the line of centers of gravity and detailed dimensions sufficient to check the general contour of the leading and trailing edges.
 - (3) Curve of maximum section thickness plotted against radius.
 - (4) Blade cross-section at frequent intervals (preferably every 6 inches).
 - (5) Chord and angle at each cross-section. (The section ordinates should also be given at the 10% stations of the blade chord. The leading edge section should be further divided into four equal sections and the ordinates given.)

- (6) When tipping is used, all details thereof.
- (7) If the material is laminated, the extent and thickness of the laminations.
- (8) A desired diameter reduction indicated on the blade planform by dotted lines.
- (9) When a different pitch distribution from that of the basic model is desired, the stations and blade angles listed in a table on the drawing, and the model designation which applies to that pitch distribution.

2. A complete material specification list should be noted or referred to on the drawing. The standard Army, Navy or SAE specification should be referred to whenever possible. The exact finish to be used on each part of the propeller should be noted.

3. All dimensional tolerances should be specified or reference made to a table of these tolerances.

4. Drawings should preferably be accordion-folded to a 9 by 12 in. size with the title block showing.

5. Altered blueprints or altered photostats are not acceptable as they are a possible source of controversy.

.202 1. Duplicate drawings. If a small number of drawings are submitted they may be in duplicate in which case a sealed set will be returned by the Authority upon certification. In cases where a large number of drawings are involved much simplification is effected by submitting one set of drawings and a duplicate parts list. The parts list should be headed with the model number and date of issuance. It should show the drawing number, last change letter, and the name of each component part. Drawing numbers should be arranged numerically. Upon certification of the propeller the parts list will be sealed and returned for inclusion in the manufacturer's files. The drawings are filed in a general drawing file for each manufacturer, hence identical drawings for different models need not be re-submitted.

.203 1. The log should either be supported by the manufacturer's affidavit or signed by the witnessing inspector. A graphical or tabular engine log with 15 minute readings is acceptable. All stops should be noted and accounted for. Tests on other than fixed-pitch wood propellers must be witnessed by an inspector of the Authority or an authorized agent (See 14.21-1 herein) and the test log will be signed by such witness. Tests on conventional fixed-pitch wood propellers will ordinarily not be witnessed by an inspector. A new manufacturer's initial test will always be witnessed. Form CAA 14-2 (Appendix) has been developed to cover the nessed. Figure 16 includes the essential items of this type of test report and is available upon request. This type of report or its equivalent should be used.

FIG. 16 - FIXED-PITCH WOOD PROPELLER TEST REPORT1. Test Data

- (a) Propeller Model No. _____ Serial No. _____
(b) *Airplane License No. _____
(c) Engine Model No. _____ Serial No. _____
(d) *Total Period of Testing _____ hrs., including
_____ hrs. at _____ rpm.
(e) **Total Period of Testing _____ hrs. at _____ rpm.

2. Test Report

- (a) Comment on any evidence of excessive flutter or vibration during test. _____
(b) Comment on any forced stops occurring during test. _____
(c) Describe tachometer calibrations made _____

3. Inspection after test

- (a) Tipping and attachment:
Tipping cracked excessively _____
Rivets or screws loose _____
Satisfactory _____
Comments _____
(b) Condition of all wood joints:
Blade lamination joints opened up _____
Hub lamination joints opened up _____
Satisfactory _____
Comments _____
(c) Condition of hub bolt holes:
Elongated or burned _____
No distortion _____
Comments _____

Figure 16 continued -

(d) Condition of wood in general:

Longitudinal cracks _____
 Transverse cracks _____
 Comments _____

4. Conformity check

Item	Drawing	Measured
Overall Diameter		
Hub Diameter		
Hub thickness		
Diameter of hub bolt circle		
Station ____: chord		
max. thickness		
blade angle		
Station ____: chord		
max. thickness		
blade angle		
Station ____: chord		
max. thickness		
blade angle		

I hereby certify that the above testing, inspection and conformity check was supervised by myself and that the data presented herein is true.

State of _____

County of _____ (Signed) _____

Subscribed and sworn to before me this _____ day of _____

19 ____.

(Notary Public)

* Applies to flight test only and must be supported by the airplane log.

** Applies to block test only and must be supported by the test log.

- .204 1. A stress analysis is usually requested if the propeller is of a new design. While this is of minor value in itself it is useful as a check of future design changes and as a general indication of steady stress conditions. Such an analysis need not be exact in its treatment of blade-deflection, but all assumptions should be of a conservative nature and the analysis should include the basic aerodynamic and centrifugal loadings.

.21 TESTS REQUIRED FOR PROPELLERS OTHER THAN FIXED-PITCH WOOD PROPELLERS

1. Sufficient advance notification should be given of the expected starting of a test in order to provide for an inspector for the Authority to witness the test. In some cases military inspectors are authorized to act as inspectors for the Authority. Items in the test program about which there is any doubt should be discussed with the Authority at an early date.

2. Service failures and stress measurements available to date have indicated the necessity for obtaining vibration stress measurements of metal propellers under operating conditions. This is to determine the magnitude of the vibration stresses existing in operation and to determine if a critical resonance condition exists at any point in the operating range of the propeller. The essential equipment has been previously listed in 14.03-1(e) herein. The resultant oscillogram from the stress pick-up may be calibrated to read stress directly and therefore give the magnitude and frequency of the vibration stress at the pick-up location. These pick-ups should be mounted at points on the blade tip where the stress is deemed a maximum and at several points on the blade shank. Sufficient runs should be taken to establish the phase relationship between stresses at corresponding points of different blades and to determine the magnitude and predominant frequency of the vibration stresses over as wide an rpm range as possible, i.e., from take-off rpm down to 25% of that speed.

3. Crankshaft torsigraph records should also be obtained in order to determine the torsional characteristics of the propeller-crankshaft system. These runs should be made with the engine rigidly mounted in order to eliminate from the record any secondary vibration due to engine oscillations. The torsimeter should preferably be mounted at the propeller hub. The complete operating range should be investigated.

4. Linear pick-ups of the magnetic type should be suitably mounted on the engine to record the motion along the three axes and such displacement records correlated with the blade vibration-stress measurements for future installation problems. This material is considered secondary but very helpful.

5. The investigations discussed in the preceding three items should be completed as an essential preliminary to any actual endurance running and the results thereof discussed with the Authority before such endurance testing will be authorized. Based on such preliminary investigations the following conditions will apply:

- a. If the vibration-stress survey shows no marked resonance conditions existing in the cruising or take-off regimes, the fifty hour endurance test may be run at either maximum, except take-off power and speed with a 10% increase granted for the take-off (one minute) operation or at 91% take-off power and speed with a 10% increment granted for take-off, (one minute) operation. It is recommended that 10 hours of the test be conducted at the take-off power and speed.
 - b. If the preliminary stress survey shows a marked resonance condition in the cruising regime it will be necessary to run a fifty hour test at the critical speed in addition to the testing outlined under item (a) above.
 - c. If the preliminary stress survey shows a marked resonance condition at take-off power and speed it will be necessary to run an added test under those conditions in addition to the testing mentioned under item a above. The amount of this testing will be based upon the amount of take-off operation to be expected in the normal service life of the propeller.
 - d. As an alternative to running the added test of item (c), the entire 50 hour endurance test may be run at take-off power and speed in which case no additional testing would be required. Tests mentioned under items (b) and (c) can, of course, be omitted by restricting operation of the propeller to avoid the critical conditions.
 - e. A correlation of stresses in new designs with those measured on designs with a satisfactory service record will be considered acceptable and helpful in a study of vibration-stress measurements.
6. The actual endurance test should be run on the type of engine for which certification is desired. Because of the vibration problems previously discussed it will ordinarily be impossible to assign a general power, speed and bore limitation to a propeller without further specifying the type of engine. The test should be run in minimum five hour increments, except that forced stops in these periods due to engine trouble will not affect acceptance of the test. A definite test schedule should be set up and adhered to as closely as possible. The propeller should be held to within 25 rpm of its proposed rated speed at all times during the test.

If the engine is operated at part throttle during the test suitable arrangements should be made to record the manifold pressure and a curve should be obtained showing the horsepower variation with manifold pressure at the proposed rated speed of the propeller. At each stop the propeller should be wiped off, examined, and a thin coating of used engine oil rubbed on. This applies to both steel and aluminum alloy propeller blades. The carbon and the trace of acid in the oil both clean the propeller and tend to work in and darken any crack which may have started.

7. It is essential that the pitch-changing mechanism of a controllable or automatic pitch propeller be operated throughout its usable range at least once for every hour of testing. These fifty cycles provide a check of the propeller operating mechanism throughout its full range. Any roughness in the operation of the propeller should be noted. Runs of five minute duration should also be made at approximately one degree intervals on this type of propeller whenever possible, and any variations in running characteristics should be noted. In addition to these required tests of the pitch-changing mechanism it is suggested that it be further subjected to a vigorous operation test of 500 cycles in the case of a manual control mechanism and 1500 cycles in the case of an automatic control mechanism.

- .211 1. Although the static vibration tests mentioned in 6 CFR 14.211 are not considered essential data in view of tests discussed in 14.21-1 through 4 herein, it is desired that such tests be run and submitted for possible correlation with the actual stress measurements taken. Static vibration data should be adjusted for the effect of centrifugal force by use of the formula:

$$F_r^2 = F_o^2 + CN^2$$

where F_r = resonant frequency of the rotating propeller,
 F_o = resonant frequency at zero rpm,
 N = propeller rpm, and
 C = vibration mode coefficient.

Suggested values of C for various loop and node conditions are:

C = 1.7 - 2.0 for 1-L and 1-N
 C = 6.0 - 6.2 for 2-L and 2-N
 C = 12.0 - 12.2 for 3-L and 3-N

2. A static vibration study should include a wide range of blade angles from 0 degrees to 90 degrees in order to determine the possibility of resonance conditions due to a forced vibration about the major axis. The effects of end fixity have been found to be important hence a suitable pre-loaded condition at the blade butt should be obtained to duplicate the effect of centrifugal force on that factor.

.22 TESTS REQUIRED FOR FIXED-PITCH WOOD PROPELLERS

1. The ten hour endurance block test should be run with the maximum diameter and pitch for which certification is desired. These dimensions may then ordinarily be reduced and approved without additional testing, provided that no other dimensions are materially altered and provided no increase in rating is desired. The test may be run on any internal combustion engine that may be available provided that the proposed rated rpm is maintained throughout the test. Since rpm is the only observed factor upon which approval is based it is essential that it be accurately determined. The tachometer should be calibrated before and after the test and checked with a stop-watch and revolution-counter during testing. This calibration should be noted on the test log. The speed should be held to within plus or minus 25 rpm of the proposed rating. The test may be made in suitable increments, provided that all stops are adequately explained in the test log.

2. The 50-hour flight test should be run on the same general type of airplane on which the propeller will be used and the specific diameter and pitch for which certification is desired should be installed. The engine power and speed should be equal to or greater than those for which the propeller is to be certificated and at least five hours should be run at the proposed rated speed. As the rpm is the only observed factor upon which approval is based it is essential that it be accurately determined. Suitable checks, as discussed in the preceding paragraph, should be made and noted on the test report. (See Fig.16)

.23 INSPECTION OF A TESTED PROPELLER

1. The propeller should be thoroughly inspected at the conclusion of the testing for any unsatisfactory conditions that may have developed. Pitch-control mechanisms should be thoroughly inspected for excessive wear and for clearances. A complete inspection report, considering all applicable items discussed in the following paragraphs, should be submitted.

a. Aluminum-alloy propeller blades should be etched at the tip and shank portions and at any other critical sections. Fillets, and points of abrupt curvature, are critical sections. The blades should then be examined for cracks with a 4 to 6 power magnifying glass. Particular attention should be paid within the tip portion to the region approximately one third back from the leading edge on the lower surface of the blade. Any transverse cracks or scratches near this location should be thoroughly investigated. The region of the shank in line with the leading or trailing edge of the blade should also be examined minutely.

- b. Hollow-steel blades, solid steel blades and forged steel hubs should be thoroughly inspected visually, and magnetically by the wet process. Any pronounced magnaflux indication should be reported and discussed in detail as it may warrant a complete metallurgical examination. This inspection should be made by a highly skilled operator with a long service experience.
- c. The blade control mechanism should be inspected for excessive wear, fatigue cracks, and any other unsatisfactory condition. All ferrous parts should be subjected to a magnetic inspection by the wet process.
- d. The hub cones should be carefully inspected for any signs of wear which are an indication of torsional vibration condition.
- e. Fixed-pitch wood propellers should be thoroughly examined for evidences of loosened or excessively cracked tipping, opened glue joints, cracks in the wood and local failure or cracking around the hub bolt holes. These items are adequately covered in Figure 16. A certain amount of flexural cracks in the metal tipping is considered normal.

2. The inspector for the Authority will inspect the torn-down propeller for conformity with the drawings which are to be forwarded to Washington. This inspection should be conducted and certified to by the manufacturer in the case of conventional fixed-pitch wood propeller tests. Several blade sections and other major dimensions of the blades and hub should be checked. Only a representative number of parts need be checked when a large number are involved, as in the hub control mechanism. A notation and record of the conformity inspection should be incorporated in the inspection report.

.3 MILITARY PROPELLERS

- 1. A requisite to certification of propellers of this type is the submittal of the proper forms and necessary drawings as discussed in the previous paragraphs 14.200 and 14.201, respectively.
- 2. A copy of the official report which forms the basis of the military approval or a copy of the official letter of approval from the military agency is required. The manufacturer's responsibility with respect to obtaining the letter is the same as in the case of the report. The propeller must be approved for service use. A restricted approval for additional flight test purposes is not considered sufficient.

.4 MODIFIED PROPELLERS

- 1. Small changes in pitch and diameter are ordinarily permissible in the case of fixed-pitch wood propellers without additional testing.

For the purposes of field identification it is necessary that a new model number be assigned with each change in pitch and diameter. A change in dash number in conjunction with the basic model number is recommended to designate a change in pitch. (See 14.1-B (8) herein.) A change in pitch distribution should be noted in a suitable tabular form on the basic model drawings. Small changes in diameter which involve only the tip sections may be denoted by dotted lines on the basic model drawing. The necessary forms CAA 01-9 and 14-1 should be submitted for each model.

2. Minor modifications to a metal propeller blade structure may result in major changes in the vibration stresses of the blade. This point must therefore be suitably covered if a modification is submitted as minor. In general, appreciable changes in the structure of a metal propeller will be considered a major change and subject to the test requirements of 6 CFR 14.2.

.51 SEALED DRAWING LIST

1. The sealed drawing list and sealed drawings should be kept adequately and conveniently filed at the manufacturer's office so that they are readily available for such conformity checks as may be made by representatives of the Authority. It is preferable to file each model separately in numerical order.

.52 MAJOR CHANGES

1. Major changes to a propeller, as discussed in previous paragraph 14.4, will necessitate compliance with the test requirements of 6 CFR 14.2 and are treated as creating new designs. If there is any doubt as to whether a change is minor or major in nature, the decision should in all cases be referred to the Civil Aeronautics Authority.

.53 MINOR CHANGES

1. Drawings including the minor changes made to the propeller during the preceding six months should be submitted during January and July of each year. If a drawing list was originally submitted the revised drawing list should also be included. If a drawing list was not originally submitted a duplicate set of drawings should be forwarded so that either a sealed drawing list or set of sealed drawings may be returned for file.

.54 REDUCTIONS IN DIAMETER

1. Reductions in diameter made by cutting off the tip or by telescoping will generally be certificated without additional testing, provided the original design has no critical resonance conditions and it is shown that no additional critical resonance conditions are encountered in the smaller diameter blade.

CIVIL AERONAUTICS AUTHORITY MANUAL

SUGGESTED FIXED-PITCH WOOD PROPELLER INSPECTION FORM

Shipped to _____			Date Mfd. _____			Des.No. _____		
Address _____					Serial No. _____			
Wood Source _____					Date rec'd. _____			
Hub Drilled _____					by _____			
Hub Installed _____					by _____			

Station	Angle	Plus or Minus	Width	Plus or Minus	Max. Thick- ness	Plus or Minus	Template Fit	Remarks

	Measured	Plus or Minus
Prop.Diameter		
Hub Diameter		
Hub Thickness		

Balance _____
 Track _____
 Finish _____
 Inspected by _____
 Approved by _____

FIG. 17